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BLAST ANALYSIS AND BLAST RESISTANT DESIGN OF R.C.C RESIDENTIAL BUILDING

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ABSTRACT

Need of designing certain important structures to resist blast loads is gaining importance day by day due to increase in terrorist activities from the recent years. Blast forces causes loss of structural integrity due to partial or complete collapse of structural members. Blast loads are dynamic loads that must be calculated carefully as that of other dynamic loads. This paper presents effect of blast loads on 5 storey R.C.C building. Effect of 100kg Tri nitro toluene (TNT) blast source which is at 40m away from the building is considered for analysis and designed. Blast loads are calculated manually as per IS: 4991-1968 and force time history analysis is performed in STAAD Pro. The influence of blast loads on structure is compared to that of same structure in static condition, The parameters like peak displacements, velocity, acceleration are studied.

Key words: Beam-column joint, Force Time-history, Story drifts, Time-displacements, Uplift force.

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1. INTRODUCTION

The term blast refers to release of enormous amount of energy from the blast source that lasts for few milli-seconds. General buildings are not designed for blast loads due to which design loads because of explosion are quite high, Blast loads primarily depend on weight of charge taken and distance between source and the target. Through out the force-time profile the force above ambient level is positive phase that lasts for very small duration and below the ambient level is Negative phase of duration that lasts for longer duration of time, Quazi Kasif et al.,(2014) investigated the effect of blast load on G+4 frame structure said that variation of displacement is varying along the height of building[1] Amole et al.,(2013) has done blast analysis of structures said that intensity of positive phase duration decreases as charge weight

increases[2] Umesh et al.,(2015) performed design and analysis of blast load on structures said that most optimal model is framed regular which showed good lateral stability [3]Sarita et al.,(2015) has made computation of blast loading for multi storied framed building observed that blast scaled distance (Z) and blast pressure are inversely proportional to each other[4] Ngo et al.,(2007) presented an overview of blast loading and blast effects on structures concluded that raising ductility levels increases the performance of building for blast loading[5]. H.R.Tavakoli et al.,(2013) concluded that the response of building is more when standoff distance is less because it is one major parameter in analyzing blast effects[6] E.Kowasarina et al.,(2012) compared experimental results and results obtained by Cole's formula and given that equivalent mass of Hexogen to TNT explosive mis 1.34[7], Based on above studies the present study is aimed to study with variation of force due to blast is calculated manually for every beam-column joint at each and every storey level and analysis is performed using force time history method in Staad-Pro software and finally make the structure resistant to the applied blast loads.

1.1. Blast Force-Time History

The force for the assumed charge weight and scaled distance is calculated manually by using IS:4991-1968 and the variation of force for different time intervals is also calculated manually for each beam-column joint.

Time history loads are applied for each beam-column joint along dead and live loads and analysis is performed by using finite element method in STAAD Pro for the following structural model shown in figure 2. Time history loads developed due to blast loads have high intensity initially and gradually decrease to zero in very small interval of time, application of blast load is similar to wind load application on structure but the difference is blast is impulse load which lasts for very short period of time say few milli second's

2. MEMBER AND LOAD SPECIFICATIONS

Column's	: 0.23 m x 0.5 m
Beams	: 0.23 m x 0.4 m
Slab	: 120 mm
Dead load (IS 875-Part 1)	: 4 KN/m^2 for slab
	: 9.38 KN/m^2 for outer walls
	: 4.27 KN/m^2 for inner walls
Live loads (IS 875-Part 2)	: 2 KN/m^2 for slab
	: 3 KN/m^2 for corridors
	: 1.5 KN/m^2 for top slab
Blast load	: calculated manually as per IS:4991-1968 and given in Table.2
Combination load	: 1.5 (Dead load +Live load)
	: 1.2 (Dead load+ Live load)
Materials used	: M25,Fe415

Earthquake and wind loads are not applied due analysis of with blast loads because probability of Occurring all the three at a time is negligible

3. METHODOLOGY

The following flow chart drawn below represents analysis and design of RCC building in step wise procedure. The method used for blast analysis is Time-history analysis by which we can apply blast force as an impulse load because blast force does not prevail for longer period of and it last's for a few milli-seconds, so time-history method is most suitable for designing a building for blast loads and the method used for preliminary design is static analysis by imposing dead, live loads and combination loads

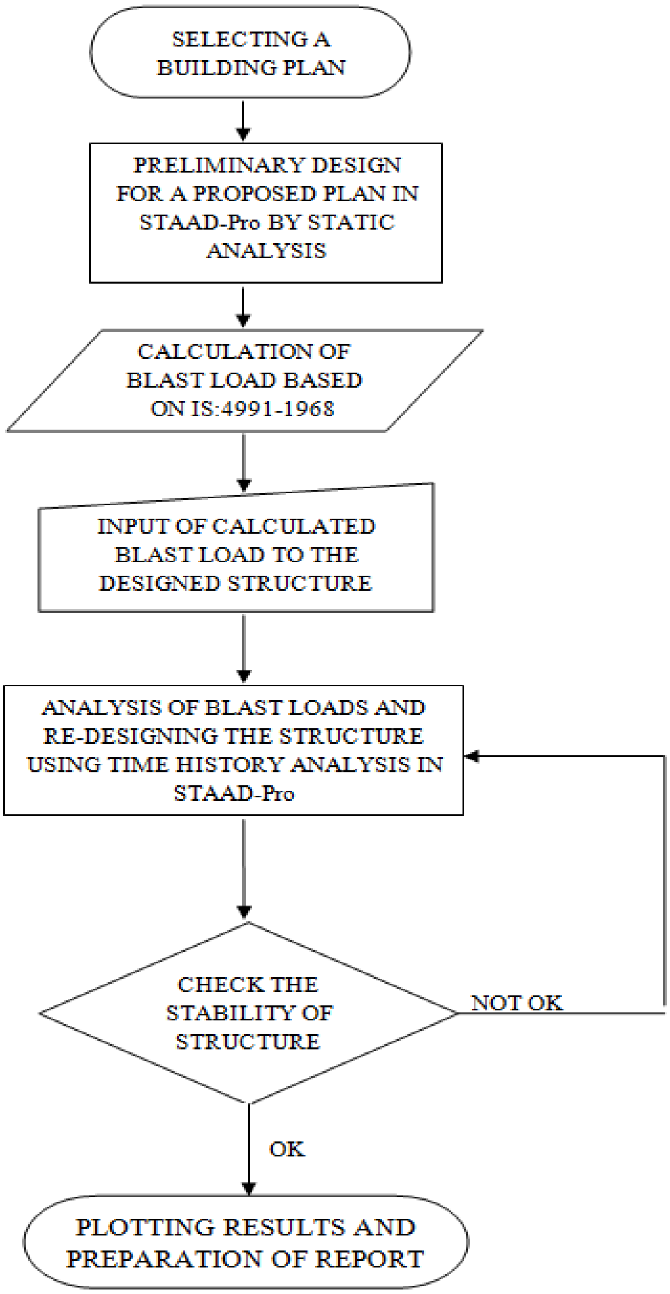

Figure 1

The building for the present study is G+5 residential building consisting of 4 bays in Z-direction and an overall span of 15.5m and 17m in X-direction. The typical storey height is 3 meters and overall height of the building is 18m from the ground level. Pseudo Static analysis is performed for the proposed plan by considering dead loads ,live loads taken from IS:874

part 1 and IS:875 part 2.The blast loads are calculated by assuming 100kg TNT which is at 40m away from the building √and 1.5m above the ground level from centre of building by using IS:4991-1968 for every beam column joint that varies with time intervals.

The distance for each beam-column joint varies from the source which are calculated manually and tabulated below by using two point formula, considering blast source at a point (0,1.5,0) at centre.

$$(x,y,z) = \sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2} \quad (1)$$

Where (x_2,y_2,z_2) varies for every beam column joint shown in Table 1

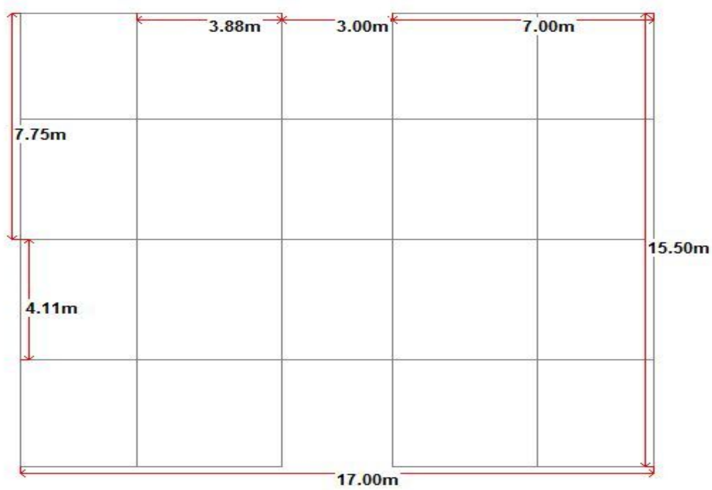

Figure 2 Top view of the proposed plan

4. RESULTS AND DISCUSSION

The blast loads are calculated by using the above distances and charge weight 100 KG by using the following formula

$$\text{Scaled distance (m)} = \frac{\text{Actual distance}}{\text{charge weight in tonnes}} \quad (2)$$

The corresponding values of P_{ro} , Ps_o , t_r , t_d , t_o are taken from Table 1 of IS:4991-1968 for calculation of blast loads which are tabulated in Table 2.The decrement of blast load varying with every with 5 milli-seconds is calculated by using the following equations

$$P_s = P_{so} (1-(t/t_0)) e^{-t/to} \quad (3)$$

$$q = q_o (1-(t/t_o)) e^{-2t/to} \quad (4)$$

where,

P_s is side-on over pressure

P_{so} is peak side-on over pressure

t_o is time for positive phase of side on over pressure

t is time at present

q is dynamic pressure

q_o is peak dynamic pressure

The peak pressure is developed when the blast waves strike the surface of the building which is perpendicular to the direction of propagation of the wave and gradually decreases to zero,The Peak side-on over pressure develops when blast waves does not have obstruction in their direction of propagation of wave but develop the drag force on the members and the pressures obtained in Table 1 of IS:4991-1968 are converted into force by multiplying with

area contributing to beam column joint are given Table 2 acting on front face of the building which lasts for 20millisecond's.

Table 1 Distance from blast source and the target point

CO-ORDINATES OF POINT OF INTREST			DISTANCE BETWEEN SOURCE AND TARGET	SLAB
40	1.5	0	40.0	SLAB 1
40	1.5	4.11	40.21	
40	1.5	7.75	40.74	
40	4.5	0	40.15	SLAB 2
40	4.5	4.11	40.36	
40	4.5	7.75	40.99	
40	7.5	0	40.44	SLAB 3
40	7.5	4.11	40.90	
40	7.5	7.75	41.18	
40	10.5	0	41.0	SLAB 4
40	10.5	4.11	41.20	
40	10.5	7.75	41.72	
40	13.5	0	41.76	SLAB 5
40	13.5	4.11	41.96	
40	13.5	7.75	42.47	
40	16.5	0	42.72	SLAB 6
40	16.5	4.11	42.91	
40	16.5	7.75	43.41	

Table 2 (P_{ro}) Blast load on front face of the building

SLAB	SCALED DISTANCE	Pro (kg/cm^2)	Pro (KN/m^2)	A (m^2)	Force (KN)
SLAB 1	86	0.51	50	2.7	135
	86	0.51	50	2.7	135
	87	0.5	49	2.1	103
SLAB 2	86	0.51	50	2.7	135
	87	0.51	50	2.7	135
	88	0.5	49	2.1	103
SLAB 3	87	0.5	49	2.7	132
	87	0.5	49	2.7	132
	89	0.49	48	2.1	101
SLAB 4	88	0.49	48	2.7	130
	89	0.48	47	2.7	127
	90	0.47	46	2.1	97
SLAB 5	90	0.47	46	2.7	124
	91	0.46	45	2.7	122
	92	0.46	45	2.1	95
SLAB 6	93	0.43	42	1.95	82
	93	0.43	42	1.95	82
	94	0.42	41	1.35	56

The force obtained from the above table are applied on the front face of the building which is exposed to blast, and the peak side on over force (which don't have any obstruction in the direction of propagation of the wave) is calculated separately and applied on the sides of the building as shown in figure 3.All the time history forces (blast loads) applied on the building are impulsive forces which will be acting for very short period of time but may have permanent deformations.

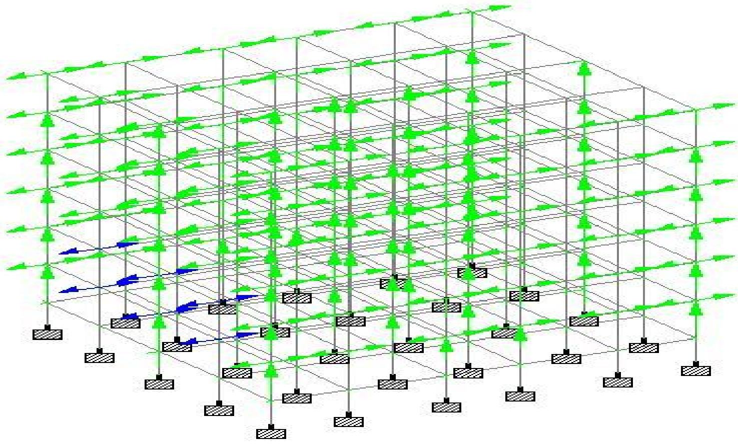

Figure 3 Representing the Application of Blast load

The peak side-on over pressure P_{so} is obtained from Table 1 of IS:4991-1968 and the corresponding force 88.8KN lasting for about 20 milli-seconds which is calculated manually is applied on sides of the building which are applied using force time history in STAAD Pro for every beam column joint which are calculated manually using IS 4991-1968 and the maximum nodal displacement's, velocity, with variation of time immediately after applying blast loads is as follows

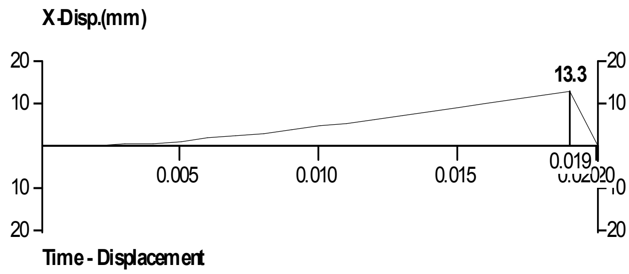

Figure 4 Representation of maximum nodal time- displacement on top most storey

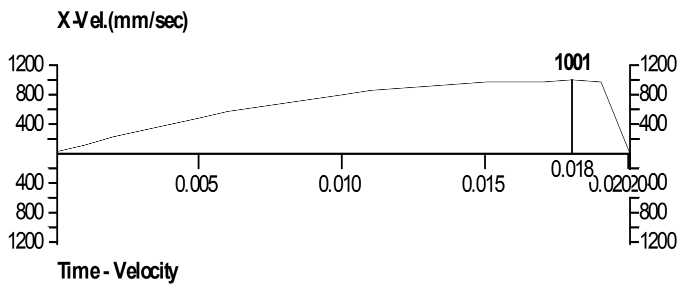

Figure 5 Representation of Time-Velocity on the top most storey which is maximum

Revision in design is done due to failure of members due to application of blast loads which are as follows

Column's	: 0.3m x 1m for outer column's
	: 0.23m x 0.5m for inner column's
Beam's	: 0.23m x 0.5m for all beam's
Materials	: M30, Fe415

Analysis is carried out after revision in design which is satisfying all structural requirement's and the results are as follows

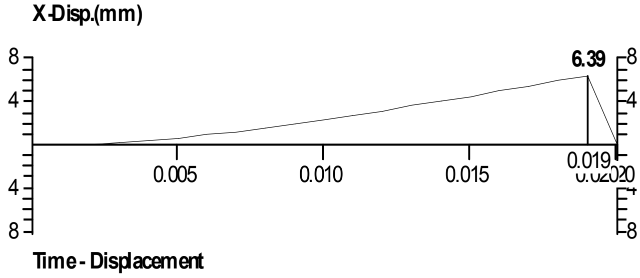

Figure 6 Representing average nodal time-displacement of top storey after revision in design

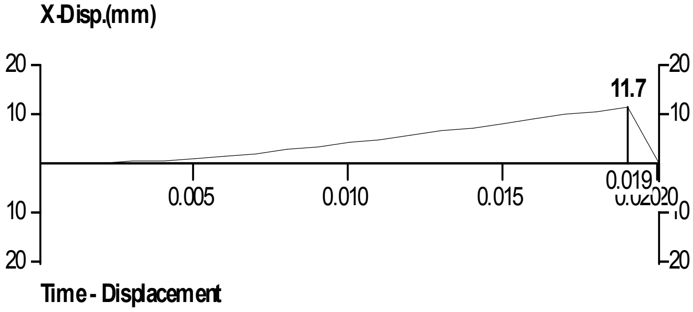

Figure 7 Representing maximum nodal time-displacement after revision in design

However maximum storey drift's are in permissible limits which is less than H/500 after revision in design of structural members

Where,

H-Height of individual storey

Table 3 Frequency and Time period of different mode shapes

Mode	Frequency (Hz)	Period (sec)
1	3.744	0.267
2	3.770	0.265
3	4.768	0.210
4	5.178	0.193
5	5.296	0.189
6	5.296	0.189

The natural frequency of the building obtained from analysis is 12.94Hz which does not match with any of the mode shape frequency and by this we can say the building is safe from resonance effect.

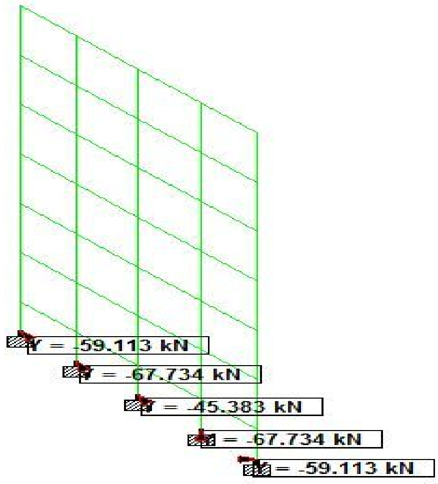

Figure 8 Representing Uplift force at supports on Front face of the Building

It is observed that uplift force comes into picture immediately after the application of blast force and the uplift force for the proposed charge weight 100KG on the building subjected to blast force is very small when compared to dead weight of the building, so that it can resist uplift force developed by 100KG blast source.

5. CONCLUSIONS

Blast resistant design refers to improving structural integrity of structure instead of complete collapse of building ,The present study on G+5 Residential building proves that Increase in stiffness of structural members by increasing in size proving better results which also resist the uplift force on footings by increasing in dead weights.

Effects of blast loads can also be decreased by providing lateral moment resisting frames like shear wall thereby decreasing the effect of lateral loads which also reduces damage and increase structural integrity of the building.

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